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Diagnostic Accuracy of a New Clinical Test (the Thessaly Test) for Early Detection of Meniscal Tears

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Background: Clinical tests used for the detection of meniscal tears in the knee do not present acceptable diagnostic sensitivity and specificity values. Diagnostic accuracy is improved by arthroscopic evaluation or magnetic resonance imaging studies. The objective of this study was to evaluate the diagnostic accuracy of a new dynamic clinical examination test for the detection of meniscal tears.

Methods: Two hundred and thirteen symptomatic patients with knee injuries who were examined clinically, had magnetic resonance imaging studies performed, and underwent arthroscopic surgery and 197 asymptomatic volunteers who were examined clinically and had magnetic resonance imaging studies done of their normal knees were included in this study. For clinical examination, the medial and lateral joint-line tenderness test, the McMurray test, the Apley compression and distraction test, the Thessaly test at 5° of knee flexion, and the Thessaly test at 20° of knee flexion were used. For all clinical tests, the sensitivity, specificity, false-positive, false-negative, and diagnostic accuracy rates were calculated and compared with the arthroscopic and magnetic resonance imaging data for the test subjects and the magnetic resonance imaging data for the control population.

Results: The Thessaly test at 20° of knee flexion had a high diagnostic accuracy rate of 94% in the detection of tears of the medial meniscus and 96% in the detection of tears of the lateral meniscus, and it had a low rate of false-positive and false-negative recordings. Other traditional clinical examination tests, with the exception of joint-line tenderness, which presented a diagnostic accuracy rate of 89% in the detection of lateral meniscal tears, showed inferior rates.

Conclusions: The Thessaly test at 20° of knee flexion can be used effectively as a first-line clinical screening test for meniscal tears, reducing the need for and the cost of modern magnetic resonance imaging methods.

Level of Evidence: Diagnostic Level I. See Instructions to Authors for a complete description of levels of evidence.

Meniscal injuries are very common among professional and amateur athletes and are one of the most common indications for knee surgery[1]. The evaluation of such injuries is not always easy, especially in the setting of primary health care[2-4]. The diagnosis can be made accurately in 75% of such knees on the basis of the history alone[3,4], whereas the specific clinical tests that have been used for the detection of such injuries do not have high sensitivity and specificity values[1].

A commentary is available with the electronic versions of this article, on our web site (www.jbjs.org) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

In order to improve diagnostic accuracy, arthroscopic evaluation of the knee joint had been initially proposed[5,6]. For both orthopaedic surgeons and primary health-care physicians, magnetic resonance imaging has currently become the most widely used noninvasive imaging method for detecting meniscal injuries, with a reported diagnostic accuracy of as high as 98%[7,8]. However, the cost of magnetic resonance imaging scans is high, and the wide use of the method is restricted to certain health-care systems in different countries.

In this study, we present the diagnostic accuracy of a new dynamic clinical test for the detection of meniscal injuries, which can be easily performed by physicians in the outpatient setting.

Materials and Methods

Patients

Between January 2001 and December 2002, 780 patients with symptoms relating to the knee joint were examined in the sports injuries outpatient clinic of our department. From this pool of patients, all adults with a knee injury who had an initial diagnosis of a meniscal tear made on the basis of the history and the mechanism of injury were included in this study. Exclusion criteria were multiple knee injuries, a history of knee surgery, early clinical and radiographic signs of osteoarthritis, articular cartilage injuries, neurological and musculoskeletal degenerative disorders, and disorders of the synovium. All patients with abnormal findings on conventional radiographs were also excluded from the study. We did not evaluate acutely injured knees (those seen less than four weeks after the injury) as such knees are very painful and resist clinical examination and a diagnostic approach based on either magnetic resonance imaging or arthroscopy was thought to be more appropriate[9].

Two hundred and thirteen adult patients (213 knees) (group A), with an average age of 29.4 years (range, eighteen to fifty-five years), were identified, signed a consent form, and were studied prospectively. There were 157 men and fifty-six women. A diagnostic magnetic resonance imaging scan of the knee was performed on all patients. Afterward, all patients in group A underwent therapeutic arthroscopic surgery and the findings were recorded.

For the purpose of the study, another group of 197 volunteers (197 knees) (group B) was also recruited from the outpatient clinics. These subjects (the healthy controls) had no knee symptoms or history of knee disorders. They had attended the outpatient clinics for the treatment of lumbar spine and shoulder disorders, and a diagnostic magnetic resonance imaging scan of either the lumbar spine or the shoulder was indicated for all of them. Following consultation and the signing of a consent form, all patients agreed to undergo a knee examination and to have an additional magnetic resonance imaging scan of the healthy knee. The patients in the two groups were similar with regard to age, gender, body weight, and the knee being tested (Table I).

TABLE I Demographic Data on the Patients

	Symptomatic Patients (Group A)	Asymptomatic Patients (Group B)
Age* *(yr)*	29.4 (18-55)	31.1 (18-56)
Side *(no. of knees)*		
Right	115	102
Left	98	95
Gender		
Male	157	144
Female	56	53
Body weight* *(kg)*	76.2 (58-95)	78.6 (62-96)

*The values are given as the mean, with the range in parentheses.

Fig. 1-A

Figs. 1-A through 1-D The Thessaly test at 20° of flexion. **Fig. 1-A** Lateral view of a right knee at 20° of flexion.

Clinical Evaluation

All patients in both groups had a thorough clinical examination performed by two experienced examiners (T.K. and M.H., specialists in orthopaedic surgery) and a separate examination done by two inexperienced examiners (A.H.Z. and V.Z., residents). They recorded and evaluated the results of five tests: the medial and lateral joint-line tenderness test[10,11], the McMurray test[10,12] (applying mild valgus or varus compressive stress while the knee is progressively extended and the tibia is rotated), the Apley compression and distraction test[10], the Thessaly test at 5° of flexion, and the Thessaly test at 20° of flexion. The examiners were all blinded with regard to the results of the magnetic resonance imaging scans. In the case of disagreement between the examiners, a reevaluation of the patient was performed and a common decision was made.

The Thessaly test is a dynamic reproduction of load transmission in the knee joint and is performed at 5° and 20° of flexion (Figs. 1-A through 1-E). It was named in honor of the county, or prefecture, in our country, where our hospital serves as an academic medical referral center and which has a continuous, uninterrupted ten-thousand-year history. The examiner supports the patient by holding his or her outstretched hands while the patient stands flatfooted on the floor. The patient then rotates his or her knee and body, internally and externally, three times, keeping the knee in slight flexion (5°). Then the same procedure is carried out with the knee flexed at

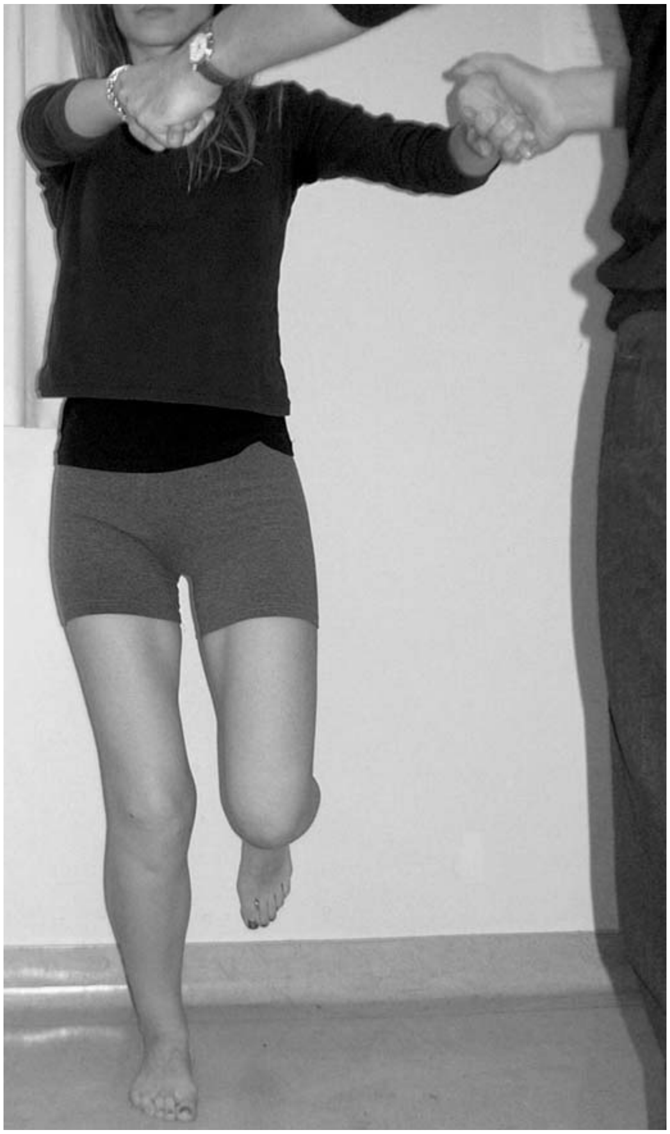

Fig. 1-B
Frontal view in neutral position.

20°. Patients with suspected meniscal tears experience medial or lateral joint-line discomfort and may have a sense of locking or catching. The theory behind the test is that, with this maneuver, the knee with a meniscal tear is subjected to excessive loading conditions and almost certainly will have the same symptoms that the patient reported. The test is always performed first on the normal knee so that the patient may be trained, especially with regard to how to keep the knee in 5° and then in 20° of flexion and how to recognize, by comparison, a possible positive result in the symptomatic knee.

Magnetic Resonance Imaging Studies

Magnetic resonance imaging scans were performed on a 1.0-T scanner (Intera NT; Philips Medical Systems, Best, The Netherlands) with use of a quadrature knee coil. The magnetic resonance sequences acquired for each patient included a sagittal fat-suppressed intermediate-weighted (repetition time, 2400 msec; echo time, 15 msec) turbo spin-echo sequence (section thickness, 4 mm; field of view, 140 × 160 mm; matrix, 256 × 304; echo train length, five) and a coronal T1-weighted (repetition time, 550 msec; echo time, 15 msec) spin-echo sequence (section thickness, 4 mm; field of view, 140 × 160 mm; matrix, 198 × 304). The acquisition times were seven minutes and thirty-six seconds and five minutes and thirty-five seconds, respectively. Magnetic resonance imaging scans were evaluated independently by one experienced musculoskeletal radiologist (A.H.K.) and one research fellow in musculoskeletal radiology. Both of them were blinded with regard to the results of the clinical tests. In cases of disagreement, a consensus was reached. A meniscal tear was diagnosed when a signal abnormality reached the articular surface of the meniscus in at least two adjacent images or when the abnormal signal reached the articular surface of the meniscus in one image of both sequences. The meniscal tears were classified, according to the systems of Mesgarzadeh et al.[13] and De Smet et al.[14], into four groups: horizontal or oblique partial-thickness tears, radial tears, vertical or complex full-thickness tears, and tears with displaced meniscal fragments.

Fig. 1-C
Frontal view in external rotation.

Fig. 1-D
Frontal view in internal rotation.

Statistical Analysis

Sensitivity, specificity, false-positive, false-negative, and diagnostic accuracy values were calculated for all clinical tests[15]. The chi square test was used to determine whether the findings on the imaging studies for the symptomatic patients and asymptomatic controls were significantly different[16]. A p value of <0.05 was considered to be significant.

Before the study was begun, an error analysis of the clinical evaluation was conducted on twenty patients. The four examiners, who later examined the two groups of patients, showed an initial interobserver and intraobserver agreement of 95% for all clinical tests.

Ethical Aspects

The study design was approved by both the National Ethical and the Hospital Scientific Committees. All patients in both groups were fully informed and signed a consent form for participation in the study.

Results

Magnetic Resonance Imaging and Arthroscopic Findings

The findings on magnetic resonance imaging in group A included medial meniscus tears in 130 patients, lateral meniscus tears in thirty-seven patients, a combination of anterior cruciate ligament and meniscal tears in twenty patients, isolated anterior cruciate ligament tears in fifteen patients, and miscellaneous lesions (chondral lesions, plicae, or cysts) in eleven patients. Arthroscopic findings in the same group of patients were in agreement with those of the magnetic resonance images in all patients except two. Arthroscopy initially failed to visualize two nondisplaced horizontal tears of the posterior horn of the medial meniscus. Arthroscopic surgery was then performed for the treatment of all patients on the basis of the magnetic resonance imaging findings.

The findings on magnetic resonance imaging in group B included a normal appearance of all knee structures in 188 patients and medial meniscus tears in nine patients (4.6%). The tears in the asymptomatic patients were located in the posterior horn of the medial meniscus and consisted of five nondisplaced, horizontal partial-thickness tears and four oblique partial-thickness (incomplete) tears[13,14]. These types of meniscal tears do not represent Grade-I or II meniscal degenerative changes[13,14]. A significant difference was detected between groups A and B with regard to the presence of meniscal tears (chi-square test, $p < 0.001$).

Evaluation of Clinical Diagnostic Tests

The values for the diagnostic parameters for all clinical examination tests, with magnetic resonance imaging used as the

Fig. 1-E
The Thessaly test at 5° of flexion. Lateral view of the right knee.

TABLE II Values for Diagnostic Parameters of the Clinical Examination Tests

	Diagnosis		
Test	Injury of Medial Meniscus	Injury of Lateral Meniscus	Combined Injury of Anterior Cruciate Ligament and Meniscus
McMurray test			
Sensitivity	48%	65%	45%
Specificity	94%	86%	76%
False positive	4.2%	12.4%	23%
False negative	17.6%	3.2%	2.7%
Accuracy	78%	84%	74%
Apley test			
Sensitivity	41%	41%	20%
Specificity	93%	86%	84%
False positive	4.6%	13%	38%
False negative	20%	5.4%	4%
Accuracy	75%	82%	59%
Joint-line tenderness			
Sensitivity	71%	78%	65%
Specificity	87%	90%	80%
False positive	8.8%	9.3%	19%
False negative	10%	2%	1.7%
Accuracy	81%	89%	80%
Thessaly test at 5° of flexion			
Sensitivity	66%	81%	65%
Specificity	96%	91%	83%
False positive	2.9%	8%	17.6%
False negative	11.4%	1.7%	1.7%
Accuracy	86%	90%	82%
Thessaly test at 20° of flexion			
Sensitivity	89%	92%	80%
Specificity	97%	96%	91%
False positive	2.2%	3.7%	9%
False negative	3.6%	0.73%	1%
Accuracy	94%	96%	90%

method to determine the disorder, are shown in Table II. The true-positive, true-negative, false-positive, and false-negative recordings for the Thessaly test with the knee at 20° of flexion are shown in Table III. The Thessaly test at 20° of flexion showed high values for diagnostic accuracy, with an accuracy level of 94% in the diagnosis of medial meniscal tears and 96% in the diagnosis of lateral meniscal tears. In knees with a combination of an anterior cruciate ligament and meniscal tear, the diagnostic accuracy of the Thessaly test for meniscal tears reached the level of 90%. Identical values were produced when arthroscopy was used for the determination of the disorder. The rates of false-positive and false-negative results, expressed as a percentage, for all clinical tests are also shown in Table II. When the Thessaly test at 20° of flexion was used to identify medial meniscal tears, false-negative results were recorded for seven knees in group A and eight knees in group B. When the test was used to identify lateral meniscal tears, false-negative results were recorded for three knees in group A. Magnetic resonance imaging analysis of the knees with false-negative recordings showed partial-thickness medial meniscal tears and nondisplaced horizontal tears of the lateral meniscus. The rest of the clinical examination tests showed inferior diagnostic accuracy values and a higher number of false-negative and false-positive recordings, with the exception of the joint-line tenderness test, which showed an acceptable accuracy value at the level of 89% in identifying lateral meniscal tears (Table II).

All isolated medial meniscal tears found on magnetic resonance imaging produced medial joint-line tenderness, and all isolated lateral meniscal tears found on magnetic resonance imaging produced lateral joint-line tenderness.

When the Thessaly test was performed at 20° of flexion, seven (3.3%) of the patients in group A had a clinically impor-

TABLE III Recordings of the Thessaly Test at 20° of Knee Flexion*

	Positive	Negative	Total
Medial meniscal injury			
Positive	124 (a)	9 (b)	133 (a + b)
Negative	15 (c)	262 (d)	277 (c + d)
Total	139 (a + c)	271 (b + d)	410
Lateral meniscal injury			
Positive	34 (a)	15 (b)	49 (a + b)
Negative	3 (c)	358 (d)	361 (c + d)
Total	37 (a + c)	373 (b + d)	410

*True-positive (a), false-positive (b), false-negative (c), and true-negative (d) recordings.

tant exacerbation of knee symptoms, requiring the administration of analgesic tablets, and one patient had the knee lock, requiring manipulation with the patient under anesthesia in order to unlock it. No subject in group B experienced any side effects during the clinical examination.

During the study, the four examiners continued to have interobserver and intraobserver agreement of >95% on all clinical tests.

Discussion

Meniscal tears occur as a result of injury or degeneration of the substance of the meniscus. Most patients report an acute onset of sharp pain following a twisting injury with the knee flexed and the foot planted on the ground[3,4,17,18]. The pain typically subsides after a period of time, and the patient usually reports pain and discomfort in the affected part of the joint. Recurrent effusions are common and, occasionally, a locking sensation is felt. Physical examination of the knee with a torn meniscus reveals joint-line tenderness with a palpable click or snap. The range of motion may be limited secondary to displacement of a meniscal tear.

Several provocative maneuvers or tests have been described to elicit symptoms from a torn meniscus. They can be divided into two groups[1,10]. In the first group are those tests that depend on palpation to elicit tenderness or clicks, such as the Bragard, McMurray, and Steinmann second test[1,10]. In the Bragard test, the examiner palpates the joint line and demonstrates that external tibial rotation and knee extension increases the tenderness across the joint line. The McMurray test demonstrates a palpable click at the joint line[12]. Medially, this is demonstrated with external tibial rotation and passive motion from flexion to extension. Laterally, it is demonstrated with the tibia in internal rotation and passive motion from flexion to extension. The Steinmann second test demonstrates joint-line tenderness that moves posteriorly with knee flexion and anteriorly with knee extension.

In the second group are the tests that depend on pain with rotation[1,10]. The Apley test forces the tibiofemoral surfaces together in flexion to elicit pain. This is believed to confirm a meniscal tear. The Apley test is also performed with the knee surfaces distracted. If this test elicits less discomfort than the compression test, it favors the finding of a meniscal tear over that of a fixed articular cartilage disorder. The Bohler test is performed with varus stress and compression to demonstrate a medial tear and with valgus stress and compression to diagnose a lateral tear. Duck walking increases the compressive forces on the posterior horns of the torn menisci and causes pain. The Helfet test is a failure of the knee to externally rotate normally with extension and is seen when the knee is locked. The Steinmann first test is done with the knee flexed to 90°, and sudden external rotation of the tibia is applied to test the medial meniscus. The result is pain along the medial joint line. Internal tibial rotation is used for lateral meniscal tears. The Merke test is the first Steinmann test with the patient in the weight-bearing position. Internal rotation of the body produces external rotation of the tibia and medial joint-line pain when the medial meniscus is torn. The opposite occurs when the lateral meniscus is torn. Although the Merke test is a dynamic test, it differs from the Thessaly test because of the fact that it is performed at 90° of knee flexion with partial bipedal weight-bearing. To the best of our knowledge, no clinical examination test similar to the Thessaly test has been reported in the literature.

The McMurray test is the most widely used test, and it is found to be positive in 58% of knees with a torn meniscus[19]. Others believe that joint-line tenderness is the most accurate clinical sign of meniscal tears, as it is present in 77% to 85% of such cases[11,18,19]. Despite the wide use[1,2,10] of these tests, their sensitivity and specificity and diagnostic accuracy are low[1]. Moreover, the reports describing them in the literature are old and very few of the tests have been studied to determine how their diagnostic accuracy compares with that of arthroscopy or magnetic resonance imaging[5,6,11,20-26]. In the later studies, the sensitivity and specificity of the clinical tests, mainly the McMurray test, rarely exceed the level of 80%. These tests have a high rate of false-positive findings, and their diagnostic accuracy does not improve with the examiner's experience; therefore, it seems that all have a limited value in current clinical practice. The joint-line tenderness sign only can be safely used for the detection of lateral meniscal tears[11]. Thus, in order to improve diagnostic accuracy in the detection of meniscal tears, arthroscopic evaluation was initially proposed[5,6]. This procedure has a cost and subjects the patient to the risks of a surgical procedure. More recently, despite the substantial cost, magnetic resonance imaging scans have been widely used as a screening tool for meniscal tears. On the basis of the high predictive value of negative findings on magnetic resonance imaging studies, it has been suggested that magnetic resonance imaging can be used in order to exclude patients from unnecessary arthroscopy[13,14,27,28].

For the last three years in our department, we have used this new clinical test for the early and accurate detection of meniscal tears. It has been developed by one of us (T.K.) to reproduce the exact dynamic mechanisms that cause meniscal injuries in humans. It can be inferred that the dynamic (monopodal weight-bearing) internal and external rotation of the knee at 20° of flexion squeezes apart the fragments of the meniscus and causes pain arising from the outer intact part of the meniscal substance, which is innervated[29,30]. Because the meniscal load is increased substantially with this maneuver, we believe that even small tears can be detected with this test.

In order to evaluate the diagnostic accuracy of the Thessaly test, a control group of subjects with healthy asymptomatic knees was used[31,32]. We did not use symptomatic knees with no suspected meniscal abnormality or the asymptomatic contralateral knee of the patients in group A as controls because studies have shown that such knees are associated with a high prevalence of meniscal tears (perhaps because of overstressing of the noninjured knee or because of lifestyle risk factors), which introduces bias[31,32]. This clinical examination maneuver with the knee at 20° of flexion was tested against both arthroscopy and magnetic resonance imaging and demonstrated high sensitivity and specificity rates and a diagnostic accuracy of 94% for tears of the medial meniscus and 96% for tears of the lateral meniscus, which are comparable with the accuracy rates reported for magnetic resonance imaging[7,8]. The same maneuver at slight flexion (5°) did not show equivalent accuracy rates. The other clinical diagnostic tests reviewed showed low accuracy rates, and we do not recommend them.

All clinical tests showed a high rate of interobserver and intraobserver agreement. This can be explained by the fact that an error analysis of the clinical evaluations was performed prior to the initiation of the study. The joint-line tenderness sign (for the lateral meniscus only) showed an acceptable, although lower than previously reported, accuracy rate of 89%[11]. In our study, the presence of a disorder of the anterior cruciate ligament rendered the clinical examination tests less effective in the diagnosis of a meniscal abnormality, which is comparable with the findings in other reports[20]. In our study, the findings of arthroscopy and magnetic resonance imaging were found to be in agreement with respect to the diagnosis of meniscal tears in the vast majority of the knees. Arthroscopic evaluation failed to diagnose two meniscal tears, and magnetic resonance imaging studies demonstrated a meniscal abnormality in 4.6% of the asymptomatic patients, which is lower than the rates reported in other studies[31,32]. A possible explanation is that our control group (group B) comprised volunteers who did not have any knee problems at all, whereas the control groups in other studies have consisted of the asymptomatic knee in patients with a symptomatic knee[32].

The Thessaly test at 20° of knee flexion has low rates of false-negative and false-positive results. This allows it to be used safely as a first-line screening test[15] for the diagnosis of both medial and lateral meniscal tears. This test has recently changed our everyday clinical practice. We use its results for the selection of patients who need arthroscopic meniscal surgery. We continue to use magnetic resonance imaging scans as a second-line screening test for those patients in whom the history, mechanism of injury, and clinical examination indicate the existence of a disorder other than a meniscal injury. This diagnostic approach has allowed us to decrease substantially the cost of diagnostic imaging as fewer magnetic resonance imaging studies are necessary. ■

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